WATER RESOURCE MANAGEMENT

Dead Sea: Death march or turnaround strategy?

Throughout history, the Dead Sea basin has served as a source of refuge and inspiration for followers of Judaism, Christianity and Islam, writes Handré Brand. Today, the religious significance of the Dead Sea is being overshadowed by its rapid disappearance. Institutional, social, gender and economic issues related to water management options for the Dead Sea basin are thus far more complex than what is currently envisioned by engineers and policymakers. These issues need to be addressed adequately to achieve equitable and sustainable water management (Lipchin 2006).

The Jordan River drainage area forms a unique and delicate freshwater ecosystem. It stretches from the Lebanon Highlands and Hermon Mountain ranges to the Dead Sea over a distance of 223 km in a north-south direction. The height of the water level of the Dead Sea is (at the time of writing) indicated as 437 m below sea level. This is consequently the lowest-lying landmark on Earth (Sevil and Gutiérrez 2023). The salt concentration of the water is about 340 grams per liter.

Today, the Dead Sea area is experiencing serious environmental problems, such as a decrease in the water level, increases in the salinity of the water, and the emergence of sinkholes on the shore. It is crucial to investigate the causal factors of the phenomena and put together effective action plans to conserve and efficiently maintain the Dead Sea and the Jordan River Rift Valley as natural assets.

The relatively rapid decline over the past few decades in the water supply from the Jordan River to the Dead Sea and the accompanying sinkhole crisis may be indirectly linked, according to Popperl (2018), to two important historical disputes over the Dead Sea Valley's economic resources. First, as early as 1920, the British Mandate governments of Palestine and Jordan granted prospecting rights to Jewish industrialist, Moshe Novomeysky, to mine potash and other minerals in the Dead Sea area. In 1952, the Israeli government took over Novomeyski's interests, centralised the industry, and established the Dead Sea Works Ltd. This industry pumps salt water on a large scale from the north to evaporation coils in the south in order to extract minerals.

The second issue concerns Israel and Jordan's ongoing competition to obtain water rights from the Jordan River. This dispute has resulted in several million cubic meters of water being diverted annually from the Sea of Galilee to the Israeli National Water Canal System, below the Deganya Dam.

Professional water management is crucial to ensuring that the available and precious water resource is distributed equitably among the interested riparian countries (especially Israel, Jordan, and the Palestinian Territories as well as Lebanon and Syria to a lesser extent), while still maintaining the ecological balance of the Dead Sea ecosystem. The Jordan River, the main source of water for the Dead Sea's supply, is experiencing a significant decrease in water flow, ***inter alia***, related to human activities such as regional population growth, agricultural development, and domestic use.

Therefore, it is essential to compile innovative water management action plans in order to avoid further disagreement and conflict. Should the drastic deterioration of the Jordanian system continue, it will have serious geopolitical implications for all interested parties and the risk of reaping the (dangerous) fruits will become an unpleasant reality.

According to Nissenbaum (1993), the economic significance of the Dead Sea region can be seen above all in its historical role in relation to tourism, industrial development, and agriculture. The Dead Sea area yields agricultural products such as salt, potash, and bromide, as well as sugarcane, dates, and balsam. Asphalt deposits have been used for waterproofing purposes and other religious rituals such as mummification from time immemorial. The water of the Dead Sea possesses therapeutic and medicinal properties, and this hyper-salty water source (water with salinity higher than sea water) is particularly popular among tourists.

However, declining water levels and environmental degradation pose a threat to all sectors. Therefore, studying the potential future of the Dead Sea can provide valuable insights into promoting sustainable economic development and securing individuals and groups that rely on the region's resources. In this regard, physical geographer Ibrahim Oroud (2023) tested a hypothetical energy balancing model based on a monthly time interval of 800 years. The aim of the study was to predict the future (simulated) height of the water level, total water area, and water temperature of the Dead Sea under different scenarios such as varying freshwater inflows and a wide spectrum of atmospheric variables.

Projections suggest that the Dead Sea is developing toward a reduced hypersaline hot lake (dwarfed hypersaline hot lake). The period necessary for the Dead Sea to reach a quasi-stable equilibrium spans hundreds of years. However, simulation and forecasting data such as the above should always be treated as approximate information, due to the complexity of the systems involved, the long integration period involved, and uncertainties caused by variations in the local climatological variables.

The Dead Sea region contains a wealth of geological and archaeological artifacts, providing valuable insights into Earth's development history and ancient civilizations. It is at the same time an artifact of tectonic activity. Further research by climate professionals and the environmental and geosciences are determinants in understanding past climatic conditions, changes in the landscape, and human history, thereby fostering an understanding of the environment's history and its significance for the future.

The Dead Sea area is constantly exposed to global heating and climate changes such as modified rainfall patterns and rising temperatures. The surface temperature of the Dead Sea area rises by about 0.6°C per decade (Kishcha 2018). Climate changes should necessarily have a further impact on the saltwater lake and surrounding karst topography just as is the case with comparable regions such as the Great Salt Lake in Utah.

The purpose of this article is to discuss some points of view regarding the falling water level of the Dead Sea and to raise the question of whether a reversal to limit this escalating natural disaster is a feasible possibility.

Sinkhole development

According to Sevil and Gutiérrez (2023), the development of sinkholes is geomorphic in nature. Briefly put, it is a process by which the Earth's surface is altered by physical and chemical factors. Sinkholes are responsible for increasing economic losses worldwide. The presence of sinkholes in the highly dynamic salt rock (karst) of the Dead Sea is a striking example of the way in which human behavior increases the risk of sinkhole development.

Since 1980, the coastal area of the Dead Sea has been characterised by the emergence of thousands of sinkholes because the level of salt water is constantly decreasing. The relatively rapid development of sinkholes in the Dead Sea area presents an extraordinary opportunity to study their evolution. The evolution of the morphometry and distribution of sinkholes provides essential information on which risk assessments for future trends are based.

Sevil and Gutiérrez (2023) conducted multi-temporal cartographic analyses in a specific sector on the west shore of the Dead Sea. The database allows for aerial and satellite footage, high-resolution three-dimensional photogrammetric models, and fieldwork. The sinkholes mapped by these researchers indicate singular, small, relatively shallow, and semicircular sinkholes located within larger sinkhole basins. From 2005 to 2021, 702 new sinkholes appeared in the area in which the surveys were made. An average subsidence rate of 45 cm/year was calculated for the karst area where sinkholes occur.

There are currently over 5 000 mapped sinkholes in the Dead Sea Area (Yizhaq, Ish-Shalom, Raz, and Ashkenazy 2017). These sinkholes are observed mainly along the edge of a salt layer deposited during the Plio-(youngest) Pleistocene epoch. The bigger Lake Lisan (precursor to the Dead Sea which stretched 70 000 to 15 000 years BC to the Sea of Galilee) retreated during this epoch, thus forming the present smaller Dead Sea (Frumkin, Ezersky, Al-Zoubi, Akkawi, and Abueladas 2011).

There exist two (and often conflicting) schools of thought about the causes of the emergence of sinkholes in the Dead Sea area (Ezersky and Frumkin 2013). One point of view is that the sinkholes are structurally controlled and are limited to tectonic fault lines, based on observations and data obtained through seismic surveys. According to this, the sinkholes are therefore basically fault-line-induced.

The second explanation model emphasises that sinkholes arise as a result of the solution of subsurface salt layers due to the displacement of hypersaline (hypersaline) groundwater by brackish/unsaturated groundwater with lower salinity (Frumkin ea 2011). This amounts to aggressive (or unsaturated) groundwater draining from adjacent and underlying Judea aquifer (see the sketch below) into the lower-lying Dead Sea and in this way promoting sinkhole formation.

In conjunction with this, sinkhole formation is indirectly promoted by the sharp decline in the Dead Sea's water level (with a drop of 34 m over the past 50 years and more recently increased at a rate of more than a meter per year).

Finally, regarding the effective monitoring of sinkhole formation in the Dead Sea Region, Ezersky et al (2014) recommends the following mode of operation: "Only a careful ground monitoring policy, year after year, coupled with geophysical measurements could allow the setting up of a predictive model concerning the propagation of hazards".

Evaporation

Shafir and Alpert (2011) conducted a pan-evaporation study in the vicinity of Sodom off the coast of the southern Dead Sea. Natural evaporation is an essential meteorological parameter especially when it comes to the industrial sector in the Dead Sea area.

The results of the study suggest that pan evaporation has increased by 20% to 25% over recent years. The causes are attributed to changing global and local climatic conditions. Global changes refer to the effect of global heating, as a result of which the frequencies of some synoptic systems in the region have been modified. The local causes refer to the falling water level of the Dead Sea resulting in a flattening in the frequency of the local Dead Sea Breeze. The Dead Sea Breeze usually tempers the local climate in the area.

Mediterranean Sea winds penetrated the Dead Sea area over time, displacing the neutralising effect of the Dead Sea Breeze on which increased evaporation followed. According to the researchers, flattening of the local wind factor was the dominant cause of increased evaporation between 1970-90. As a result, the temperature rose and the relative humidity decreased. However, at the present stage, global heating plays a crucial role in increasing evaporation, while the local factor is of secondary importance.

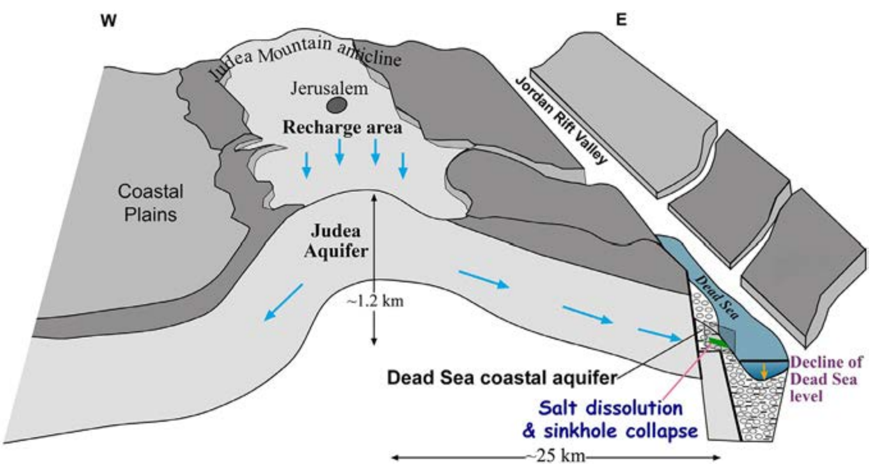
Effective water management in the Jordan River Valley

The natural flow from the Jordan River to the Sea of Galilee is estimated at 50-550 million m^3 annually (Katz 2022). In addition, the river receives an average of another 300 million m^3 annually due to direct rainfall, direct inflow of surface water, and spring water. It is then also more or less equal to the volume of water lost through evaporation. The lower-lying areas of the Jordan (between the Sea of Galilee and the Dead Sea) are fed by smaller connecting rivers such as the Yarmud, for example. The total annual discharge from the Jordan to the Dead Sea is estimated at 1 200-1 350 million m^3 per year.

The Jordan River Valley is currently under intense water pressure (hydric stress). Further complicating the assessment of the situation is the limited nature of the diverse sources of information and datasets available for research purposes, which greatly complicates their reliable interpretation. Obtaining reliable and long-term data related to climatology as well as water availability and use patterns is almost an impossible task (Comair, Gupta, Ingenloff, Shin, and McKinney 2013).

Becker, Lavee, and Tavor (2012) propose supplementing the 300 million m^3 of water pumped annually from the Sea of Galilee via a canal system to the central parts of Israel supplemented with water from desalination plants on the coastal strip of the Mediterranean Sea. This solution should prevent the water level of the Sea of Galilee from being constantly reduced. As a result, more water will be placed in the Jordan River drainage system and at the same time, provide a greater downflow to the Dead Sea.

Against this backdrop, Israeli water planners have begun to design a reverse national water channel system (Katz, 2022). The idea is that desalinated seawater is transported from the Mediterranean coast to the Sea of Galilee using a pipeline (located directly next to the canal system that carries water from the Sea of Galilee) from the Mediterranean coast to the Sea of Galilee. However, there are quality differences between desalinated water and the water of the Sea of Galilee in terms of



Schematic relationship between the eastern Judea aquifer and the Quaternary coastal aquifer of the sedimentary fill of the Dead Sea rift. (Source: Abelson, M, Y Yechieli, G Baer, G Lapid, N Behar, R Calvo, and M Rosensaft. 2017. Natural versus human control on subsurface salt dissolution and development of thousands of sinkholes along the Dead Sea coast. Journal of Geophysical Research: Earth Surface, doi:10.1002/2017JF004219.

acidity and other parameters. Thus, desalinated water cannot be let directly into the Sea of Galilee. It was then decided to release the desalinated water into a dry course (wadi), after which it flows over several 100 m using gravity to the Sea of Galilee. In the process, the desalinated water absorbs minerals and in this way, the chemical composition changes on its way to the Sea of Galilee. An artificially perennial tributary of the Jordan is thus created, from which the Jordan Valley and the Dead Sea consequently benefit immensely in terms of inflows.

The purpose of innovative water management in the Jordan region (Comair ea 2013) should meet the following criteria: (a) to promote reverence and respect for water in the consumer; to encourage reduced consumption; to better check the consumption of water; to use water more efficiently; to exploit unconventional water resources; to promote the use of purified greywater. (b) Improving the quality of existing data and information production systems to correct the current information imbalance. However, it is important to bear in mind that water management plans must be interpreted in terms of the complex context of these arid environments, intense needs for more water for local urban and rural consumption, profound cultural and political-ideological issues, suspicion, militarized boundaries, lack of trust and the frequent surge of disputes between the interested riparian countries.

Plans to connect the Mediterranean with the Dead Sea, or the Red Sea with the Dead Sea have been around for more than 100 years (Katz 2022). According to Comair ea (2013), this remains an important and relevant consideration for the essential addition of additional water to the system. However, the plan to finalize a canal link between the Red and Dead Seas was unilaterally canceled by Jordan in June 2021 because Israel (according to Jordan) "does not really show interest in the plan". The initiative was delayed for years by bureaucratic obstacles, funding issues, objections by environmentalists, and a lack of a properly functioning government in Israel over a two-year period at that time.

According to a recent online article (June 22, 2022) by Nir Hasson in Haaretz/Israel News, the Israeli Ministry of Environmental Affairs once again called on the Israeli government to dust off this infrastructure project again and put it on a fast track soon.

Concluding perspective

Is it possible that a meaningful turnaround can be accomplished? Is the return to the paradisiacal landscape described in Genesis 13:10 feasible today? "Lot looked around at the fertile plains of the Jordan Valley toward Soar. The whole area was water-rich, like the garden of the Lord or fertile Egypt".

A simplistic answer to this question is impossible, due to the nature of the underlying complex systems being worked with. Various issues such as physical, chemical, geopolitical, military, economic, psychological, and anthropological factors all contribute proportionately to the maintenance of a multi-faceted dilemma. These factors threaten to maintain the status quo and consequently the "death march" of the Jordan River-Dead Sea ecosystem.

Simply releasing larger quantities of water into the Jordan Bowl, either via canal connections from the Red Sea and/or the Mediterranean, should provide temporary relief for the Dead Sea, but it is not necessarily a sustainable long-term solution. The crux of the problem lies in consumers' internalised attitudes towards efficient water management and consumption. Echoing this, Lipchin (2006) points out that the centralisation of the Jordan River's water management system forces policymakers to look through a clouded lens at the way in which consumers respond to current water management policies.

This short-sightedness prevents the consideration of new policies such as the devolution of power to local authorities (provided that characterized by thorough, adequate, and professional management). The water use culture of communities should serve as the foundation on which amended and sustainable water policies are built. In short: by increasing the volume of water added to the system and modifying the current water use patterns using well-thought-out training programmes, then a gradual and realistic reversal of the death march is possible.

Bibliography

- Becker, N, D Lavee and T Tavor. 2012. Desalinate or divert? Coastal non-market values as a decision tool for an integrated water management policy: The case of the Jordan River basin. ***Ocean & Coastal Management***, 64: 27-36. https://doi.org/10.1016/j.ocecoaman.2012.04.008.
- Comair, GF, P Gupta, C Ingenloff, G Shin and DC McKinney. 2013. Water resources management in the Jordan River Basin. ***Water and Environment Journal***, 27: 495-504. doi:10.1111/j.1747-6593.2012.00368.x
- Ezersky, M and A Frumkin. 2013. Fault-dissolution front relations and the Dead Sea sinkhole problem. ***Geomorphology,*** 201: 35-44. https://doi.org/10.1016/j.geomorph.2013.06.002
- Ezersky, MG, LV Eppelbaum, A Al-Zoubi, S Keydar, AR Abueladas, E Akkawi and B Medvedev. 2014. Comments to the publication of D. Closson and N. Abu Karaki "Sinkhole hazards prediction at Ghor Al Haditha, Dead Sea, Jordan: "Salt Edge" and "Tectonic" models contribution"—a rebuttal to "Geophysical prediction and following development sinkholes in two Dead Sea areas, Israel and Jordan, at: Ezersky, M.G., Eppelbaum, L.V., Al-Zoubi, A., Keydar S., Abueladas, A-R., Akkawi E., and Medvedev, B. ***Environmental Earth Sciences,*** 71 (4): 1989-93. https://doi-org.ez.sun.ac.za/10.1007/s12665-013-3019-2
- Frumkin, A, M Ezersky, A Al-Zoubi, E Akkawi and A Abueladas. 2011. The Dead Sea sinkhole hazard: Geophysical assessment of salt dissolution and collapse, ***Geomorphology***, 134,1-2: 102-17 https://doi.org/10.1016/j.geomorph.2011.04.023
- Katz, D. 2022. Basin management under conditions of scarcity: The transformation of the Jordan River basin from regional water supplier to regional water importer. ***Water,*** 14: 1605. https://doi.org/ 10.3390/w14101605.
- Kishcha. 2018. Steady shrinking of the Dead Sea as a result of climate change in the Eastern Mediterranean. ***Joint Event on 5th World Conference on Climate Change & 16th Annual Meeting on Environmental Toxicology and Biological Systems***. London.
- Lipchin, C. 2006. A future for the Dead Sea basin: Water culture among Israelis, Palestinians, and Jordanians. ***Fondazione Eni Enrico Mattei Working Papers***, Paper 97.
- http://services.bepress.com/feem/paper97.
- Nissenbaum, A. 1993. The Dead Sea — an economic resource for 10,000 years. ***Hydrobiologia***, 267: 127-141. https://doi.org/10.1007/BF00018795.
- Oroud, IM. 2023. The future fate of the Dead Sea: Total disappearance or a dwarfed hypersaline hot lake? ***Journal of Hydrology***, 623:129816. https://doi.org/10.1016/j.jhydrol.2023.129816
- Popperl, S. 2018. Geological or erasure: sinkholes, science, and settler colonialism at the Dead Sea. ***International Journal of Middle East Studies***, 50 (3):427-48. DOI: 10.1017/S002074381800082X
- Sevil J and F Gutiérrez. 2023. Morphometry and evolution of sinkholes on the western shore of the Dead Sea. Implications for susceptibility assessment. ***Geomorphology,*** 434: 108732. https://doi.org/10.1016/j.geomorph.2023.108732
- Shafir, H. and Alpert, P. 2011. Regional and local climatic effects on the Dead Sea evaporation. ***Climatic Change***, 105(3-4): 455- 68. DOI 10.1007/s10584-010-9892-8.
- Yizhaq, H, C Ish-Shalom, E Raz and Y Ashkenazy. 2017. Scale-free distribution of Dead Sea sinkholes-observations and modeling, ***Geophysical Research Letters***, 44, 4944-52, doi:10.1002/2017GL073655.